Review Comments — Water Available for Replenishment
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Definition of Water Available for Replenishment

The WAFR Report says on page 12 that the definitions of water available and for replenishment can be found in the "Key Definitions" box in the "Understanding Water Available for Replenishment" section. I was unable to find that Key Definitions box in the Understanding Water Available for Replenishment section on page 13.

It is important to clearly define the term "replenishment of groundwater" at the beginning of the WAFR Report. To establish what that term means before the report gets into the details of estimating it. The following six paragraphs incorporate my understanding of how the WAFR Report appears to use the term.

Groundwater replenishment (or recharge) is the mechanism by which surface water moves from the overlying land surface and into the aquifer below or from groundwater underflow into the basin.

It appears that the estimate of water available for replenishment in the WAFR Report *excludes:*

- Replenishment that occurs naturally as part of the hydrologic cycle.
- Replenishment that occurs as a secondary benefit of actions such as deep percolation from applied agricultural and landscape irrigation water or from water placed into unlined conveyance canals.

It appears that the estimate of water available for replenishment in the WAFR Report *includes:*

- How the surface water supply is actively (intentionally) used or available for use for direct or indirect (in-lieu recharge) replenishment of the groundwater aquifer.

Water agencies already actively use surface water to directly replenish the groundwater aquifer. For the purposes of the WAFR Report, replenishment occurs when a groundwater basin is managed so that recharge is increased when compared with existing or baseline conditions, and ultimately groundwater levels are either maintained or improved. That appears to mean that the WAFR estimates of replenishment only reflect surface water above and beyond the amount currently being used to replenish the groundwater basin.

The WAFR Report makes a simplifying assumption for WAFR estimates that available water can be dedicated to groundwater replenishment. That assumption relies on two other unstated assumptions:

- Projects will be available to capture this water and put it into the groundwater aquifer.
- Water users will use this identified surface water supply for recharging the groundwater aquifer, even if estimated total surface water supplies are inadequate to meet demand. That is an unreasonable assumption. The highest priority for every GSA is to have a balanced water budget; only after achieving that will any extra water be used to replenish the groundwater aquifer.

The WAFR Report estimates surface water available for replenishment for all 10 hydrologic regions. In making those estimates, there does not appear to be a needs assessment about whether or not groundwater needs to be replenished in a particular hydrologic region. The assumption seems to be that replenishment of groundwater is desirable, even in those hydrologic regions where groundwater replenishment already significantly exceeds groundwater pumping (e.g., North Coast, San Francisco, Central Coast, Sacramento River, North Lahontan, and South Lahontan). That seems like an unreasonable assumption.

The above is my understanding of how the WAFR Report uses the term "water available for replacement." I may have it wrong. If so, that just underscores the need to clearly define the term early in the report.

Methodology for estimating Water Available for Replenishment

Once the term "water available for replacement" has been clearly defined, it is important to clearly define the concept of how it is estimated. The WAFR Report and appendixes contain a number of details about this methodology. But the concept needs to be introduced early in the report.

The Executive Summary explains why the report was required, and it summarizes the major findings. But it fails to connect the dots between the two; it needs to present the general methodology of how DWR went about generating the estimates of water that is available for replenishment.

It is important to explain to the reader, at the beginning, just what methodology the analysts used in calculating the estimates that are presented in the report. Don't make the reader try to figure this out by reading the entire report and the appendixes, gathering bits and pieces like assembling a jigsaw puzzle.

After reading the entire report and the appendixes, I'm still not completely clear about the methodology that was used. The following eight paragraphs incorporate my understanding of how the WAFR Report calculated the estimates of water available for replacement of groundwater.

The WAFR Report doesn't appear to clearly state what time period it was estimating water available for replacement of groundwater for. My guess is that it was for the 1967 through 2012 time period.

The methodology begins by estimating total water demand, surface water supply, and groundwater use, all based on historical data. Total demand was simulated based on the year 2010. Supply was simulated using 1967 through 2012 precipitation and regional import data.

The methodology simulates outflow by comparing the historical supply for 1967 through 2012 against total demand for 2010. After meeting demands, the remaining runoff is outflow from the hydrologic region. The methodology (as presented on page 23) makes the unstated assumption that total surface water supply will exceed total demand. There is no provision in the methodology for those hydrologic regions where estimated total surface water supply is insufficient to meet total demand (e.g., Tulare Lake and Colorado River).

The methodology then looks at historical gage data at a river mouth that represents actual outflow conditions that result from changing levels of demand, regulations, and operations over the period when gage data are available. The methodology also identifies a potential conceptual project on that river which could have diverted surface water for the purpose of groundwater replenishment. This is water that was historically flowing out of the region, but could have been captured by this conceptual project and made available for use in the region; a new source of water.

The methodology makes the simplifying assumption for WAFR estimates that available water can be dedicated to groundwater replenishment. That may be a reasonable assumption in those hydrologic regions where total surface water supply exceeds total demand, generating a projected outflow from the region. But that is not a reasonable assumption in those hydrologic regions where estimated total surface water supply is insufficient to meet total demand. Any new-found source of surface water in those regions will be needed to balance the water budget, to make up for that deficit. The highest priority for every GSA is to have a balanced water budget; only after achieving that will any extra water be used to replenish the groundwater aquifer.

The methodology then synthesizes the simulated outflow from the hydrologic region with the historical fraction of the historical gage record that the conceptual project would have made available for replenishment of groundwater.

The above is my understanding of how the WAFR Report estimates water available for replacement of groundwater. I may have it wrong. If so, that just underscores the need to clearly describe the methodology early in the report.

Water Balance (page 30)

The Hydrologic Region Results Summary Pages presents the water balance for water year 2010 from the California Water Plan Update 2013. That is useful because it shows actual uses of water for that year, where users chose to apply water.

The Hydrologic Region Results Summary Pages also presents Surface Water Information including estimates of total water demand and surface water supply. This information is presented in a format that suggests a water balance, just like the 2010 water balance right above it. However, the WAFR demand and supply estimates are not balanced; sometimes there is a surplus and sometimes there is a deficit. This should be called out to the reader's attention.

One of the report's findings on page 8 says that "Understanding the relationships between water supply and water use is foundational to estimating the amount of surface water available for groundwater replenishment." That sounds reasonable. But the WAFR Report only discusses this in the situation where there is an estimated water surplus in a hydrologic region. It does not discuss the situation where there is a water shortfall; how this would affect the water available for replenishment of groundwater.

Definition of the terms Demand and Applied Water Use (page 30)

The WAFR Report defines Demand as "Total demand, including urban indoor, urban outdoor, agricultural, and refuge." Defining demand as being total demand isn't much of a definition; it isn't really a definition at all.

The WAFR Report also uses the term Applied Water Use but does not define that term. I assume that Applied Water is being used in the same way that it has been defined and used in the California Water Plan Updates. It is very difficult in the Water Plan Updates to tell how the terms Demand and Applied Water differ; they appear to be essentially identical. Likewise, it is hard to tell how the WAFR is using the two terms.

When I look at the Hydrologic Region Results Summary Pages (e.g., page 44), it appears that Water Demand is the same as Applied Water, but excludes Wild and Scenic dedicated water. If that is the case, it should be called out to the reader's attention, and the term "Applied Water" should be clearly defined.

Definitions of the term Runoff (page 30)

The WAFR Report defines Runoff as **"**Rainfall, snowmelt, or irrigation water, in excess of what can infiltrate the soil surface and be stored in small surface depressions." That sounds like a relatively straightforward definition of runoff, the way most people understand and use the term. But I had a lot of difficulty understanding how the term was really being used in the WAFR Report.

From looking at the Hydrologic Region Results Summary Pages, the term Runoff appears to include all the sustainable components of water supply except Regional Imports. I don't see how a reasonable reader could be expected to infer that from the definition of Runoff given above.

I think Runoff includes some combination of the following components of water supply:

1. The volume of surface flow from an area. This is the way the California Water Plan water portfolios define and use the term Runoff. More specifically, the water portfolios and Water Plan Updates define runoff (or runoff – natural) as the portion of precipitation that runs off the land and makes up the natural flow in rivers. That is the way most people generally think of runoff.
2. Reuse of return flows – urban
3. Reuse of return flows – wetlands, instream, Wild and Scenic. The water portfolios and the California Water Plan Update 2013 include Wild and Scenic dedicated water in this category (or grouped under the category of Reuse & Sweepage). Once such dedicated water flows through the Wild and Scenic river segments, it is reclassified and made available for use (technically, for reuse) by agriculture and urban users. But I think the WAFR Report excludes Wild and Scenic dedicated water from both the supply and demand side of the water balance.
4. Natural recharge of groundwater, groundwater recharged from natural application of water. This is water that infiltrates the soil surface from precipitation or from streambeds.
5. Artificial recharge of groundwater, groundwater recharged from surface application. This is water that infiltrates the soil surface from irrigation or as the result of other human influence.

If these are in fact the components of Runoff, it would be very helpful to call them out for the reader. Especially since some of these components seem to conflict with the definition of Runoff given in the WAFR Report.

The various components of Runoff (whatever they are) are combined and presented as a single number on the Hydrologic Region Results Summary Pages. It would be very helpful to know what the values of those components are. Ideally these components should be shown on the Hydrologic Region Results Summary Pages. That is how the water balances were presented in the California Water Plan Update 2013 (see Vol 2, TL-56 of the California Water Plan Update 2013). Alternative, this could be presented in Appendix A as a simple table where the rows are the hydrologic regions and the columns are the various components.

Projection of Runoff (Appendix A, page 6)

The WAFR Report does not disclose what the estimates of surface runoff and precipitation are for the various hydrologic regions; it combined all the locally derived sources of water supply. But we can see how these estimates were derived. The Central Valley Planning Area WEAP model was used to determine the runoff, demand and outflow for the Tulare Lake Hydrologic Region.

The WEAP model simulates historical surface runoff for the WAFR Report using 1967 through 2012 precipitation data. That makes the unstated assumption that the precipitation and surface runoff for the period 1967 through 2012 is representative current conditions. But that is not a reasonable assumption.

Multiple studies have shown that conditions have changed in the last three decades; data for the decades prior to the mid-1980s is not reflective of conditions in the decades since then. This is especially true for the Pacific Southwest Climate Subregion and the Tulare Lake Hydrologic Region.

Estimating surface runoff using data from the period 1967 through 2012 cannot be relied on to give a reliable estimate of runoff during the last three decades. For example, average surface runoff for the four largest rivers in the Tulare Lake Hydrologic Basin from 1967 through 2012 was 25% greater than actual runoff for the last three decades (from 1987 through 2015). Conditions really have changed, and we ignore this change at our peril.

Projection of Regional Imports

The components of Regional Imports (Central Valley Project, State Water Project) are combined and presented as a single number on the Hydrologic Region Results Summary Pages. It would be very helpful to know what the values of those components are. Ideally those components should be shown on the Hydrologic Region Results Summary Pages. That is how the water balances were presented in the California Water Plan Update 2013. Alternative, this could be presented in Appendix B as a simple table where the rows are the hydrologic regions and the columns are the components.

Imports for the State Water Project and Central Valley Project were determined based on historical flows from these projects for the years 1967 through 2012.

I was expecting the estimate of regional imports (CVP+SWP) to be about 3.16 MAF for the Tulare Lake Hydrologic Region since that is what it actually averaged during the period 1998 through 2010. Instead, the WAFR Report estimated regional imports to be 2.14 MAF, 32% less than what had been delivered during the 1998 through 2010 period.

Even after reading Appendix B, I was not able to understand how the Regional Imports estimates were derived. I couldn't find the connection between all the analysis and the final numbers that were presented on the Hydrologic Region Results Summary Pages. There seemed to be a step missing that explained how the two were connected; how the analysis led to the result.

Groundwater information shown on Hydrologic Region Results Summary Pages (page 31)

The summary page for the Tulare Lake Hydrologic Region (page 44) shows that estimated groundwater applied recharge for this region is 2.93 MAF. Page 30 says that the source for this information is the California Water Plan Update 2013. I looked through Vol 2 (Regional Reports – Tulare Lake Hydrologic Region) of the California Water Plan Update 2013, but was unable to find this citation. The report should be clearer about the source for this information so that the reader can find it.

The Hydrologic Region Results Summary Pages presents estimates of groundwater pumping and recharge (both natural and applied recharge). No estimate is provided for groundwater withdrawals that aren't recharged. This is a very important number since SGMA requires that it be discontinued. I think this component can be calculated by subtracting groundwater total recharge from groundwater pumping. If that is correct, this should be called out to the reader's attention.

If I understand correctly, the WAFR Report estimates that the Tulare Lake Hydrologic Region has been using an average of 1.55 MAF per year of groundwater withdrawals not recharged. The WAFR Report and the WEAP model do not seem to directly account for how users will respond when this component of groundwater withdrawals is discontinued. This represents a 10% decrease in average water supply in the Tulare Lake Hydrologic Region. The unstated assumption seems to be that removing this won't have a significant effect on the crops that are planted, the relationships in the WEAP model, etc. groundwater supplies water supply is reduced by this much. That is an unreasonable assumption. When that much water is removed from supply, an equivalent change has to be made to demand unless additional supply can be made available.

The WAFR estimates water available for replenishment for all 10 hydrologic regions. From looking at the hydrologic regions summary pages, it appears that there are several hydrologic regions where total recharge already significantly exceeds groundwater pumping (e.g., North Coast, San Francisco, Central Coast, Sacramento River, North Lahontan, and South Lahontan). In such situations, there seems to be no need for groundwater replenishment. If that is correct, this should be called out to the reader's attention.

The need for groundwater replenishment does not appear to be mentioned or taken into account anywhere in the WAFR Report. The unstated assumption seems to be that an unlimited amount of groundwater replenishment is needed, more is better. The WAFR Report should address whether it takes the need for groundwater replenishment into consideration when estimating the amount of water available for replenishment of groundwater.

Projection of water available for replenishment in the Tulare Lake Hydrologic Region (Appendix A, pages 126-127)

Estimate of Total Demand for the Tulare Lake Hydrologic Region

Demand (that is, actual use or amount of applied water) for water year 2010 presented in the California Water Plan Update 2013 was supported by an equivalent amount of dedicated and developed water supply. That made for a balanced water budget.

The WAFR Report estimated total demand for the Tulare Lake Hydrologic Region as 11.75 MAF. This is roughly similar to the California Water Plan Update 2013 which estimated total demand (excluding Wild and Scenic dedicated water) for water year 2010 as 11.4 MAF. The water portfolio value for total demand averaged 11.52 MAF for years 1998 through 2010 (the most recent available years). So the WAFR estimate seems comparable to our recent experience.

But this estimate of demand is an almost meaningless term since there is no balanced water budget; the demand is not supported by an equivalent amount of dedicated and developed water supply. (There is a deficit of 1.28 MAF.) Demand is only meaningful if it is supported by available dedicated and developed water supply. GSAs will have to adjust either demand or supply (or both) in order to achieve a balanced water budget and end groundwater overdraft. That should be called out to the reader’s attention.

Estimate of Total Runoff for the Tulare Lake Hydrologic Region

The WAFR Report estimated total runoff for the Tulare Lake Hydrologic Region as 8.33 MAF. The water portfolio value for total runoff averaged 8.36 MAF for years 1998 through 2010 (the most recent available years), very similar to the WAFR estimate.

It is hard to know how to actually compare these two figures because the WAFR Report is unclear about what assumptions it makes in estimating demand and supply. The WAFR Report needs to clearly state its assumptions so that the reader knows what the estimates are based on. Is Wild and Scenic dedicated water included in the estimates of demand and supply? Are groundwater withdrawals that are not recharged included in the estimates of supply?

The water portfolio and the Water Plan Updates are based on balanced water budgets. If a change is made to the demand side, an equivalent change has to be made to the supply side. Although unstated, it appears that the WAFR Report excluded Wild and Scenic dedicated water when estimating demand. Therefore, the above 8.36 MAF value for the water portfolio *excludes* an average 1.57 MAF in Reuse of return flows – wetlands, instream, Wild and Scenic. When Wild and Scenic dedicated water is removed from the demand side, an equivalent amount has to be removed from the supply side in order to keep the water budget balanced.

If I understand correctly, the WAFR Report estimates that the Tulare Lake Hydrologic Region has been using an average of 1.55 MAF per year of groundwater withdrawals not recharged. It is unclear whether the WAFR Report includes those groundwater withdrawals when estimating Runoff. So for comparison purposes, that 8.36 MAF value for the water portfolio average for years 1998 through 2010 *includes* the equivalent groundwater withdrawal component. That seems somewhat reasonable since water users really did use that source of water during those years. The question is why the water portfolio value of 8.36 MAF (which includes this groundwater component) is so similar to the WAFR estimate of 8.33 MAF (which may or may not include this groundwater component). There are two possibilities:

- The WAFR estimate of runoff *includes* the 1.55 MAF per year in groundwater withdrawals that are not recharged as a component of Runoff even though such withdrawals are to be discontinued under the provisions of SGMA. That would seem unreasonable since it is prohibited by law, at least in the future that the GSAs are planning for.
- The WAFR estimate of runoff *excludes* the 1.55 MAF per year in groundwater withdrawals that are not recharged as a component of Runoff because such withdrawals are to be discontinued under the provisions of SGMA. If that is the case, then the WAFR estimate is estimating a surface water supply sufficiently large to make up for that source of water. That would be unreasonable. If the WAFR estimate of runoff really represented existing conditions, then there would have been no need for water users to have turned to overdrafting the groundwater aquifer overdrafts in the first place.

The above comparison was made *including* groundwater withdrawals that are not recharged in the water portfolio data. The comparison can be done *excluding* that component. The water portfolio value for total runoff averaged 7.12 MAF for years 1998 through 2010 (the most recent available years). Based on that, the WAFR estimate of annual runoff (8.33 MAF) is 1.21 MAF (15%) higher than our most recent experience.

This leaves us with the same issue; the WAFR Report appears to have found a major new source of water, nearly equivalent to the amount of groundwater withdrawals that are not recharged. That seems unreasonable. The WAFR Report is effectively estimating a new source of water that we were not aware of. A source of water that would be the equivalent of the average annual flow of the Kaweah, Tule, and Kings Rivers, combined.

It isn’t clear why the WAFR Report overestimated available surface water supply by so much. One likely possibility is that the report based surface runoff based on a non-representative sample of years. The estimate of runoff in the WAFR Report is a reflection (maybe an average) of available water based on precipitation for the years 1967 through 2012. Multiple studies have shown that using data from years before the mid-1980s will tend to result in an over-estimate of existing conditions. The average surface runoff for the four largest rivers in the Tulare Lake Hydrologic Basin for the last three decades has decreased 13% to 20% compared to the average for the previous nine decades. Conditions really have changed since about the mid-1980s.

The average combined surface runoff for those four rivers from 1967 through 2012 was 25% greater than actual runoff for the last three decades (from 1987 through 2015). This all suggests that the 8.33 MAF estimate is a significant overestimate of the amount of water supply available under existing conditions.

Estimate of Total Regional Imports for the Tulare Lake Hydrologic Region

The WAFR Report estimated total regional imports for the Tulare Lake Hydrologic Region as 2.14 MAF. The estimate was determined based on a reflection of (and maybe an average of) historical flows from the State Water Project and Central Valley Project for the years 1967 through 2012.

The water portfolio value for total regional imports averaged 3.156 MAF for years 1998 through 2010 (the most recent available years). So the WAFR estimate of annual runoff is 1.02 MAF (47%) less than our most recent experience.

That was unexpected, and there is nothing in the WAFR Report to explain the reason for this big decrease. The report needs to make a clear case for why the estimated historical imports are so much less than our most recent experience. As currently written, this estimate seems unsupported by the data.

Estimate of Water Available for Replenishment for the Tulare Lake Hydrologic Region

The net result of all these estimates is that the WAFR Report estimates that there will be a 1.28 MAF deficit in total water supply necessary to support estimated total water demand.

Any new-found source of surface water will be needed to balance the water budget, to make up for that deficit. The highest priority for every GSA is to have a balanced water budget; only after achieving that will any extra water be used to replenish the groundwater aquifer.

Let's start with the water balance for water year 2010 as shown in Vol 2, page TL-57 of the California Water Plan Update 2013.

The Tulare Lake HR is nearly a closed basin. The primary outflow location is the James Bypass that connects the North Fork of the Kings River with the Mendota Pool on the San Joaquin River. Water typically only leaves the Tulare Lake HR through the James Bypass when flood control releases from Pine Flat Dam exceed demands, or when there are high, unregulated natural discharges from Mill and Hughes creeks.

The WAFR Report used USGS gage records to determine historical flows through the James Bypass. Flow through this reach has not historically been related to water supply in the Tulare Lake Hydrologic Region. Flows are only sent through this reach during periods of very high water when there is no other place to make productive use of water within the hydrologic region. The WAFR Report determined what fraction of these floodflows was available for replenishment of groundwater.

There seem to be a number of stated and unstated assumptions here.

- The water that flows through this reach of the James Bypass is a good measurement of the water that is available for replenishment of groundwater in the Tulare Lake Hydrologic Region. That is not a reasonable assumption. Flows through the James Bypass are best thought of as just floodflows; a potential source of water supply, similar to flows through the Delta. The important measure of potential water available for replenishment of groundwater is whether supply exceeds demand.
- No change to the amount of these floodflows (water lost to the region) will occur as the GSAs try to make up for the deficit of 1.28 MAF per year in water supply. That is not a reasonable assumption. It is much more likely that the region will look to untapped sources of water such as the floodflows that now flow through the James Bypass as it discontinues its reliance on groundwater withdrawals that are not recharged.
- The floodflows through this reach of the James Bypass can be dedicated for replenishment of groundwater in the Tulare Lake Hydrologic Region. That is not a reasonable assumption. If it were easy to tap these floodflows for groundwater replenishment, they would have been tapped historically. Now as the region discontinues its reliance on groundwater withdrawals, it will be faced with a major deficit in water supply. Any new-found source of surface water will be needed to balance the water budget, to make up for that deficit. The highest priority for every GSA is to have a balanced water budget; only after achieving that will any extra water be used to replenish the groundwater aquifer.

Many of the estimates of demand, supply, and WAFR that are contained in the WAFR Report appear unreasonable because (1) many of the assumptions (stated or unstated) appear unreasonable and (2) the estimates themselves appear unreasonable when compared with our experience of recent decades, when tested against empirical data.

DWR research into the changing relationship between precipitation and runoff on the Sacramento River (page 18 of WAFR Report and pages 111-113 of Appendix A)

Figure A-SR4 compares the 1950's trend and the 1990-2015 trend of the ratio between runoff and precipitation. The WAFR Report should state what time period the 1950s trend is based on, using language parallel to the "1990-2015 trend." From looking at the graph, I infer that it may be based on the 10-year period, 1950-1960.

Figure A-SR4 displays the slope for each of the trend lines (y=26.37x and y=15.663x). Those slopes appear to represent the yield (amount of runoff for a given amount of precipitation). So the yield of the 1990-2015 trend is about 41% less than the yield of the 1950's trend. That is a huge decrease and should be called out to the reader's attention.

The two trend lines seem to have diverged most strongly beginning in about the mid-1980s. If I'm reading that correctly, that should also be called out to the reader's attention.

The second bullet on page 18 of the WAFR Report says that during multi-year droughts (e.g., water years, 1976–1977, 1987–1992, 2007–2009, and 2012–2015), streamflow as a result of precipitation is negative, indicating that water use exceeds runoff within the watershed. That is an important observation, but the use of the word "negative" does not work by itself without further explanation about the ratios that are being compared.

Both the WAFR Report and Appendix A list four factors that may contribute to the observed effect. A fifth possible explanation is that the observed trend may not be statistically significant, especially if the 1950s trend is based on just 10 years (1950-1960).

It would be useful to have a statement from the DWR researchers, the subject matter experts, as to whether this observed relationship change might be occurring in other basins or is it likely unique to basins with characteristics similar to the Sacramento.